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Dispersal of Second-Instar Western Spruce Budworm Above and Below Forest Canopies in Western Montana

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ABSTRACT

*Dispersal of second-instar western spruce budworm (*Choristoneura occidentalis*), above and below stand canopies was determined at two ecologically and physiographically distinct locations in western Montana using sticky traps. At Greenough Creek, larvae averaged 54 per trap (42 larvae per ft^2) 3 ft above the canopy and 63 (49 per ft^2) 6 ft above ground level. The difference was not significant ($p < 0.05$). Similarly, there was no difference between catches above the canopy and 6 ft above ground at Jerry Creek, even though the population was only one-fourth of the population at Greenough Creek. Significantly more larvae were caught on the north and west quadrants of the Greenough Creek traps, corresponding with prevailing wind direction. No directional influence was noted at Jerry Creek. Presence of significant numbers of small larvae above forest canopies suggests that they may be dispersed long distances during vigorous frontal systems and strong horizontal windflow. Long-distance dispersal of the insect may account for sudden population buildup in areas previously thought uninfested. To our knowledge, this is the first report of small western spruce budworm larvae caught above forest canopies.*

KEYWORDS: budworm dynamics, budworm redistribution, population movement, forest susceptibility

Successful exploitation of conifers by phytophagous insects depends on movement of insect populations to quality food. Dispersal of second-instar western spruce budworm (*Choristoneura occidentalis* Freeman [Lepidoptera: Tortricidae]) is one mechanism for movement of this important defoliator of western coniferous forests. Overwintering in bark fissures, lichens, or other suitable protective habitat, larvae emerge from hibernaculae as second instars early in spring. Larvae crawl on branches and twigs of the tree on which they emerged, searching for suitable feeding sites (Fellin and Dewey 1982). Probability of larval survival is closely related to time they spend searching for feeding sites. Larvae also disperse downward from branch to branch, attached to their silken threads. During windy periods, silks may break, and larvae, buoyed by the silks, may be blown about. How far they are carried, and in what concentrations, are not known (Carlson and others 1988). Wind may influence survival by blowing larvae to better or worse food sources. Dispersal of small budworm larvae is important to forestry because, as probability of larval survival increases, so does probability of damage to timber resources.

Dispersal dynamics of early instar western spruce budworm are poorly understood. In western Montana, where budworm populations were moderate and topography was gentle, second-instar densities (larvae per ft^2) were not different among sticky traps placed 1.6 ft above ground level, spaced evenly within clearcut shelterwood, seedtree, and selection cuts in Douglas-fir/western larch (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco/*Larix occidentalis* Nutt.) forests (Fellin 1981). But where populations were low and topography was steeper, significantly more larvae were trapped near the edges of clearcuts than near the centers (Fellin 1981). Similarly, in another western Montana study, larval density 1.6 ft above ground was not related to stand structure nor to distance from stand boundary (Carlson and others 1988). Traps placed near ground level measure population losses due to dispersal but probably are not good indicators of dispersal higher in the canopy (Regniere and Fletcher 1983). Uniform catches near ground level, independent from overstory basal area and distance from cutting boundary, suggest immigration of early instars from other stands. If long-distance dispersal of wind-entrained small larvae is important, as suggested by Carlson and others (1988), the larvae should be present above forest canopies in significant numbers. We report here a study to determine small larval dispersal above the general canopy and near ground level in western Montana Douglas-fir forests, and dispersal into an included meadow.

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METHODS

Two areas were chosen for study. The Greenough Creek site is about 20 miles southeast of Missoula, MT, on a south-facing 40 percent slope. Elevation varies from 5,000 ft mean sea level (MSL) near the stream bottom to 5,700 ft at the ridgetop. The predominant habitat type (Pfister and others 1977) is Douglas-fir/ninebark (*Physocarpus malvaceus* [Greene] Kuntze). The forest is mostly even-aged 70- to 80-year-old Douglas-fir with the dominants about 50 to 65 ft high in dense thickets. Mean basal area of conifers over 4.5 ft high was 46 ft^2 per acre, mean diameter breast height (d.b.h.) was 5.9 inches, and mean height was 30 ft. The Jerry Creek site is 120 miles southeast of Missoula, 4.5 miles northeast of Wise River, MT, at 6,000 ft MSL. The environment at Jerry Creek is quite different from Greenough Creek. Topography is undulating and varies from 0 to 30 percent slope and includes a nonforested meadow surrounded by a multistoried, uneven-aged Douglas-fir forest where the oldest trees are about 200 years and the youngest 15 to 20. Mean basal area of conifers in the forest was 68 ft^2 per acre, mean d.b.h. was 9 inches, and mean height was 30 ft. The dominants were about 65 to 80 ft high. Predominant habitat type in the forested area is Douglas-fir/pinegrass (*Calamagrostis rubescens* Buckl.). Western spruce budworm populations at both sites were deemed moderate at time of site selection because defoliation of current-year foliage in 1986 was 40 to 50 percent.

We used cylindrical traps, similar to but larger than "Oregon Traps"[2] (Jennings and others 1984), because we wanted a larger trap surface area. Traps were constructed from 3-gallon cylindrical ice cream cartons 9.8 inches in diameter and 16 inches long. Cartons were cut in half transversely, yielding two traps per carton. Polyethylene-coated freezer paper, 6 by 31 inches, was wrapped around the outside of the carton—coated side out—and stapled securely to the carton. Trapping surface was 186 inches^2 compared to about 98 inches^2 for the Oregon Trap. A sticky substance, Tack Trap, was spread uniformly about 0.1 inch deep over the surface of the freezer paper in the field as the traps were deployed.

Traps were set at two locations for each sample point in the forested areas: (1) 6 ft above the forest floor—the "ground" traps, and (2) 3 ft above forest canopy—the "treetop" traps. To support the ground traps, an 8-ft stake 3 inches in diameter was driven solidly into the ground. The sticky trap was then oriented vertically and positioned 6 ft from the ground and secured tightly with screws, with the stake on the inside of the carton (fig. 1). Treetop traps were secured similarly to the end of bamboo poles 10 ft long. The pole with attached trap was then fastened with hose clamps to the top of a dominant or codominant tree so that the trap was positioned 3 ft above the treetop (fig. 2). We designed a simple pulley system to transport the traps to the treetop so the sticky surface would not contact foliage during placement. The four cardinal directions—north, south, east, and west—were marked on the edge of each ground and treetop trap surface so we could determine from which direction the larvae came.

Traps were deployed at 10 points, one ground and one treetop trap per point, nine of which were spaced about equally on a line from the ridgetop to the slope bottom at Greenough Creek. The other point was midslope, across a small draw from the others. At Jerry Creek, 18 sample points were established on a transect beginning 400 yards in the forest west of the meadow, extending eastward through the meadow, 400 yards into the forest on the east side. The meadow was about 1,000 yards wide. Five sample points were selected along the transect at 100-yard intervals in the forest on the west and five on the east side of the meadow, such that the first point on each side of the meadow was located at the juncture of the meadow and the forest. Eight points were established at 100-yard intervals through the meadow. Ground and treetop traps were set at each point in the forest; only ground traps were deployed in the meadow. Greenough Creek traps were installed April 8-9, 1987, and collected June 12—65 days later when small larval dispersal was done. Because of cold, snowy weather, traps were not set out at Jerry Creek until April 17, 1987. They were collected May 27 and 28—40 to 41 days later when we observed that feeding larvae were mostly fourth instars.

Traps were brought to our laboratory where counts of western spruce budworm larvae were made. The freezer paper, coated with Tack Trap, was carefully removed and placed on a supportive plywood board. Traps were observed under a dissecting microscope at 30X; number of larvae were recorded by instar, trap quadrant, and trap location. The north quadrant included 315 to 45 degrees, the east quadrant included 46 to 135 degrees, and so on. Determination of species and instar was done according to Carolin and Stevens (1979) and Stevens and others (1984).

Data were analyzed separately for each area because the budworm populations and environments were not similar between locations. Differences between trap location (ground vs. treetop), plot location (upper vs. lower slope), and trap quadrant (north, south, east, west) were determined for Greenough Creek. Differences between trap location, plot habitat (forest vs. meadow), and quadrant were determined for Jerry Creek. Statistical significance was evaluated at $p \leq 0.05$, using "t" tests (Sokal and Rohlf 1969).

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[2] The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

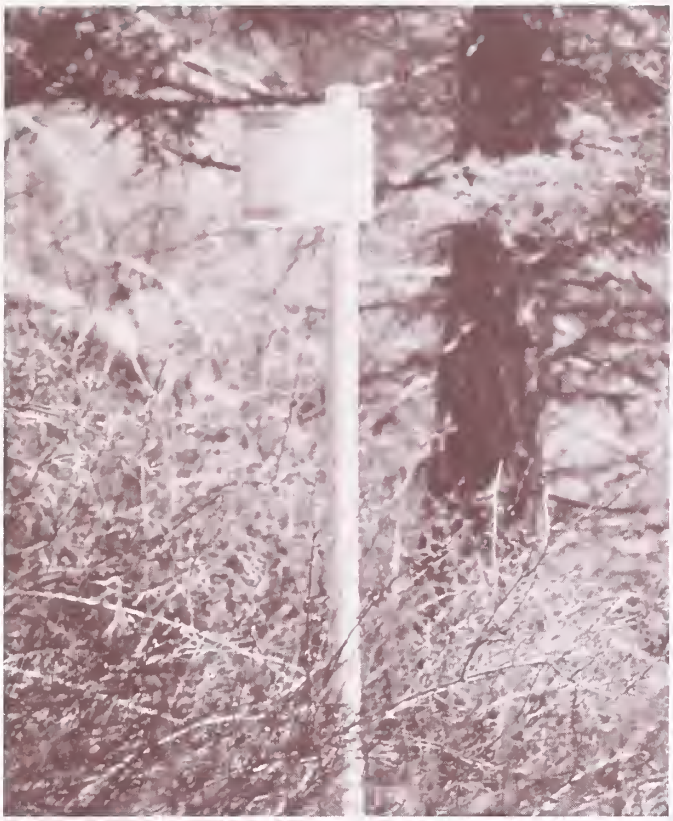

Figure 1—Ground trap deployed 6 ft above forest floor.

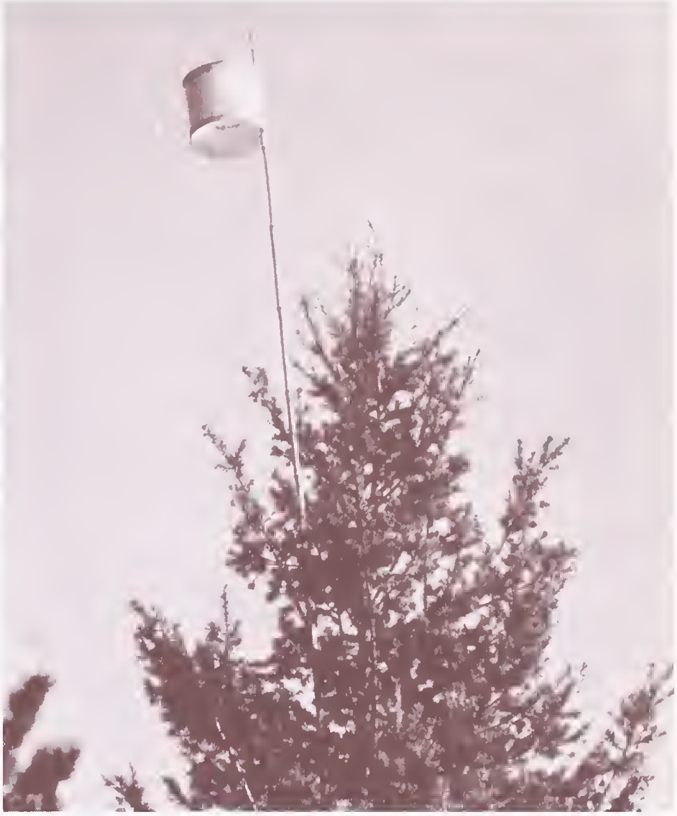

Figure 2—Treetop trap deployed 3 ft above top of codominant host tree.

RESULTS AND DISCUSSION

At Greenough Creek, catches averaged 58 instars per trap, nearly four times more than were caught at Jerry Creek, indicating a difference in populations between the areas (table 1). Even though the trapping interval differed between the two areas—41 days at Jerry Creek and 65 days at Greenough Creek—we believe the second-instar dispersal period at both areas was well covered. Traps were deployed at both areas well before bud break and were collected when most larvae were fourth instars.

Traps from the upper slope at Greenough Creek caught about the same number of larvae as traps on the lower slope, and as many larvae were captured on treetop traps as on ground traps. At Jerry Creek about 18 larvae were captured in each forest trap, nearly twice as many as in the meadow, and we detected no significant difference between treetop and ground catches, 19 and 17 larvae per trap, respectively (table 1). Of 1,369 larvae identified on the traps at both areas, 1,364 were second instars and only five were thirds. No fourth instars were found. At Greenough Creek, high winds destroyed the ridgetop tree trap, and a bear mangled two ground traps beyond salvage. At Jerry Creek, elk destroyed two ground traps.

The number of dispersing larvae declined rapidly close to the stand boundary at Jerry Creek but remained fairly constant through the meadow. About half as many larvae were captured in the meadow at Jerry Creek as were caught in the forest, and just as many larvae were caught in the middle of the meadow, 400 yards from the edge, as were caught at the edges. The mean of eight larvae in the meadow traps expands to about 261,000 per acre and the 17.6 larvae in the forest expands to about 594,000 per acre. At Greenough Creek the expanded mean was about 2 million larvae per acre. We recognize the difficulty in estimating trapping efficiency and whether catches are truly indicative of larval populations. Nevertheless, the data suggest that the number of drifting larvae is large.

At Greenough Creek, significantly more larvae were caught on the west and north quadrants of the traps, corresponding to the general westerly-northwesterly winds common in western Montana, and suggesting entrainment in laminar flows above the forest canopy. No difference in quadrants was noted at Jerry Creek, perhaps because winds were more variable there. But quadrants may not be good indicators of where the larvae came from. If the silk impacts the trap surface before the larvae, the larvae could be whipped around to a different side of the trap, depending on the length of the silk and windspeed.

To our knowledge, this is the first study reporting presence of small western spruce budworm larvae above the forest canopy during the spring dispersal season. The presence of substantial numbers of small larvae above the canopy suggests that long-distance transport may occur at this stage of the life cycle. Presumably, turbulence within the canopy dislodges small second instars, and some are carried aloft by updrafts. With their buoyancy increased by attached silken threads, the larvae may be carried considerable distance—perhaps several miles—before

Table 1—Catches of second-instar western spruce budworm by trap location at Greenough Creek and Jerry Creek, MT; April-June 1987

Area	N	Mean	Standard error	Min	Max
Greenough Creek	17	57.8	10.7	8	180
Factor					
Slope position					
Upper	7	64.6 a[1]	14.6	33	137
Lower	10	53.1 a	15.5	8	180
Trap location					
Ground	8	62.5 a	21.6	8	180
Treetop	9	53.7 a	8.0	24	98
Quadrant					
North	17	21.1 a	3.9	1	61
East	17	11.6 ab	4.2	0	64
South	17	8.4 b	1.5	0	21
West	17	16.7 a	3.1	2	54
Jerry Creek	26	14.6	2.1	3	53
Factor					
Habitat					
Forest	18	17.6 a	2.8	3	53
Meadow	8	8.0 b	1.1	4	15
Trap location					
Ground	8	18.7 a	5.3	7	53
Treetop	10	16.7 a	2.8	3	33
Quadrant					
North	26	4.2 a	.7	0	17
East	26	4.2 a	.8	0	22
South	26	3.7 a	.6	0	12
West	26	2.5 a	.6	0	12

[1] Means followed by different letters are significantly different at $p \leq 0.05$.

being deposited. Measurements of airflow were beyond the scope of our study, but recent work conducted in Canada, at a site similar to Jerry Creek, provides some pertinent meteorological clues. Under unstable atmospheric conditions during daytime, winds within a forest canopy had a strong upward component, at times exceeding 20 ft per second (14 miles per hour) (Leahey and Hansen 1987). Although these conditions occurred less than 40 percent of the time, they could easily transport small larvae above the canopy where they could become entrained in horizontal winds. Larvae are easily carried by wind. Batzer (1968) calculated velocity of fall for larvae of spruce budworm (*Choristoneura fumiferana* [Clem.]), an insect closely related to western spruce budworm. He estimated velocity to be 0.5 ft per second when silk length was 2 ft. Turbulent winds with upward velocity of more than 0.5 ft per second would tend to keep larvae with those silk lengths greater than 2 ft suspended for an indefinite time and could move them far above the canopy. Batzer also estimated that small larvae would travel 200 yards laterally when windspeed was 7 ft per second, silk length was 2 ft, and point of dispersal was 38 ft above ground. At higher windspeeds with strong upward vectors, larvae could be carried much farther.

Other work, mostly with spruce budworm in the Eastern United States, supports the notion of long-distance spread. Henson (1950) found second instars above the forest canopy, but not as many as we found in Montana. He also collected small larvae over lakes, documenting long-range dispersal. Sudden population increases in Quebec were attributed to long-distance dispersal by wind (Blais 1961). Blais (1961) reasoned that larvae were carried 7 to 8 miles from heavily infested stands to noninfested stands. Morris and Mott (1963) concluded that dispersal of small larvae can occur in sufficient numbers to cause new outbreaks in previously uninfested stands, depending on distance and weather conditions during the dispersal process. In detailed direct measurements of larval movement, Regniere and Fletcher (1983) concluded that most second-instar dispersal was horizontal, between trees within the forest canopy. Although they did not attempt trapping above the canopy, they felt that little rising of dispersing second-instars occurred. Beckwith and Burnell (1982) sampled within a conifer overstory and showed that spring dispersal of western spruce budworm in north-central Washington had a distinct horizontal component. They believed that general redistribution of small larvae would be lateral or downward.

Much of the work on dispersal of western spruce budworm has involved the use of “Montana Traps,” a sticky trap oriented horizontally about 1.6 ft above ground level (Jennings and others 1984). In a recent study, we concluded that dispersal counts obtained by using the Montana Traps were not related to local stand conditions, suggesting long-distance transport (Carlson and others 1988). Montana Traps reflect dispersal losses to the population because they catch larvae that otherwise would have been deposited on the ground, but they do not lead to good estimates of larvae dispersing elsewhere in the canopy. Regniere and Fletcher (1983) estimated that only 5 percent of the population was lost due to dispersal to the ground, and that the major direction was horizontal. Knowing now that a significant upward component of dispersal occurs, at least in the Northern Rocky Mountains, it is not surprising that Carlson and others (1988) were unsuccessful in relating stand structure to dispersal, pointing out the need in future studies on budworm population dynamics to measure dispersal within and above the canopy.

Our exploratory study provides circumstantial evidence for long-distance dispersal in the Northern Rocky Mountains. Direct evidence was not obtained, nor would it be practical to do so. The study was limited in scope. Nevertheless, because the results were consistent between two ecologically different areas, with quite different western spruce budworm populations, the conclusions appear to be credible. The probability of significant dispersal to other stands is high during outbreak periods because large quantities of small larvae are available for transport during spring when weather in the Northern Rockies is often turbulent, with numerous frontal systems moving through. The large number of larvae dispersing above the canopy could easily be entrained in these frontal systems and moved long distances—perhaps even hundreds of miles. Furthermore, the length of the dispersal period in the Rockies spans at least 30 to 40 days due to the rugged terrain and large elevational differences in the habitat of the budworm. Because emergence of second instars is delayed substantially with increasing elevation, perhaps as much as 1 day for every 300 yards' increase (Wagg 1958), the opportunity for long-distance dispersal sometime during the period is high and could result in extensive redistribution of small larvae over large areas. This may partially explain the presence of second through fifth instars we have often seen on small trees less than 3 ft tall. The proportion of larvae redistributed by this process would depend on the vagaries of weather during the dispersal period and would not be easily or accurately predictable.

Long-distance dispersal also has important implications for silvicultural treatments in budworm-susceptible forests. In thinned stands, residual trees may intercept more larvae than trees in unthinned stands, especially where populations are high. But residual trees in thinned stands may release and outgrow the deleterious effects of budworm feeding (Carlson and others 1985a). Nevertheless, threat of long-distance dispersal underscores the need to silviculturally modify the structure and composition of budworm-susceptible forests to nonhost, seral species so that future forests will not support large populations of the insect (Carlson and others 1985b). The potential for and implications of long-distance dispersal of small western spruce budworm larvae in the Northern Rockies should be recognized by foresters.

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